APPLICATION FOR

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SPECIFICATION

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Title of the Invention: DISPLAY MEASURING METHOD AND PROFILE

GENERATING METHOD

Display Measuring Method and Profile Generating Method

Cross Reference to Related Application

This application is a continuation of International PCT Application No. PCT/JP99/04588 filed on August 25, 1999.

Background of the Invention

Field of the Invention

The present invention relates to a display measuring method and a profile generating method.

Description of the Related Art

Thanks to both the spread of high-end personal computers and the low prices of image input/output devices, such as scanners, color printers or the like, the opportunities for individual users to handle color images have increased. As individual users have handled color images, color reproducibility has become a major problem. Specifically, the color of the displayed image of a display, the printed image of a printer or the like cannot be reproduced to be the same as that of an original image. This is because a color development mechanism or a color characteristic, such as a color conversion image spectrum or the like varies depending

on input/output devices. A color management system (hereinafter called "CMS") is a technology for matching the color appearance between different input/output devices. By adopting a CMS, the color appearance of

5   an image read by a scanner, that of an image displayed on a display and further that of an image outputted by a printer can be matched, thereby making the differences between the images undetectable by a user.

Today, the framework of a CMS is incorporated

10   on an OS level as in ICM (image color matching) 1.0 of Windows95 and ColorSync2.0 of Macintosh OS. By providing a user with a device profile matched with ICM1.0 or ColorSync2.0, input/output device makers can guarantee the displayed image of a display, the printed

15   image of a printer or the like, for which a user cannot detect an incompatibility, even if the user outputs the image using a different device. The device profiles of ICM1.0 and ColorSync2.0 conform to an ICC profile advocated by ICC (International Color Consortium). By

20   providing a user with a profile conforming to ICC profile specifications, input/output device makers can guarantee the use in Windows and Macintosh environments of their input/output devices.

Fig. 1 shows the basic configuration of a CMS.

25   For example, data read from a scanner 1 is

converted into common color signals that do not depend
on devices (for example, CIELAB) using a scanner profile
2. By converting the common color signals into an image
using a display profile 3 and by displaying the image,

5   the color appearance of a manuscript inputted by the
scanner 1 and that of a displayed image can be matched.
The profile stores both information for converting
signals peculiar to the device (for example, RGB values)
into   common   color   signals   and   information   for

10   converting the common color signals into the signals
peculiar to the device (that is, a profile provided
for each device).

Similarly, images generated by the scanner 1 or
a display 4 are converted into common color signals

15   (L*a*b* signals) by the scanner profile 2 or display
profile 3. Then, the common color signals are converted
into CMY (K) signals by a printer profile 5 and are
outputted from a printer 6.

To perform high-accuracy color matching, the

20   accuracy of a profile that stores the display
characteristic of a display must be improved. To achieve
this, a display measurement must be conducted without
an error.

Fig. 2 shows the structure of an ICC profile.

25   In the ICC profile, all pieces of necessary data

are described using tags. The ICC profile is composed of three parts: a profile header (128 bytes, fixed length) for representing both information about the profile itself and target equipment, a tag table for

5 representing the types of information and the storage place and tagged element data for storing actual information. Information for representing the equipment property of an input/output device is stored in the tagged element data.

10   There are two types of profiles in an ICC profile: a matrix profile used mainly for a display profile and an LUT profile used for a printer profile.

The matrix profile uses the color additive-mixture characteristic of an input/output

15 device. Color additive-mixture means that a color C(r, g, b) composed of specific RGB values r, g and b can be expressed by the sum of a color R(r, 0, 0) composed of only r, a color G (0, g, 0) composed of only g and a color B (0, 0, b) composed of only b.

20      $C(r, g, b) \equiv R(r, 0, 0) + G(0, g, 0) + B(0, 0, b)$

The matrix profile stores both the measurement values of maximum red, green and blue and color tone characteristics of red, green and blue. A color tone

25 characteristic is a relationship between input and

output values and is also called a γ characteristic. In this description, a color tone value means the output value of a color tone characteristic against a specific input value. Color tone data means the aggregate of

5　color tone values against input 0 (minimum) to 1 (maximum). By utilizing this characteristic, for example, the CIEXYZ values of an arbitrary color C(r, g, b) can be calculated according to the following equation, if it is assumed that an RGB value is 8 bits,

10　that the output values (CIEXYZ values) of maximum red (255, 0, 0), maximum green (0, 255, 0) and maximum blue (0, 0, 255) are $(X_{(255, 0, 0)}, Y_{(255, 0, 0)}, Z_{(255, 0, 0)})$, $(X_{(0, 255, 0)}, Y_{(0, 255, 0)}, Z_{(0, 255, 0)})$ and $(X_{(0, 0, 255)}, Y_{(0, 0, 255)}, Z_{(0, 0, 255)})$, respectively, and that the color tone

15　characteristics of red, green and blue are fR(r), fG(g) and fB(b), respectively.

$$\begin{pmatrix} X_{(r,g,b)} \\ Y_{(r,g,b)} \\ Z_{(r,g,b)} \end{pmatrix} = \begin{pmatrix} X_{(255,0,0)} & X_{(0,255,0)} & X_{(0,0,255)} \\ Y_{(255,0,0)} & Y_{(0,255,0)} & Y_{(0,0,255)} \\ Z_{(255,0,0)} & Z_{(0,255,0)} & Z_{(0,0,255)} \end{pmatrix} \begin{pmatrix} fR(r) \\ fG(g) \\ fB(b) \end{pmatrix}$$

A matrix profile is used to calculate a

20　relationship between input and output according to the above equation. Therefore, the profile stores the reference CIEXYZ value $((X_{(255, 255, 255)}, Y_{(255, 255, 255)}, Z_{(255, 255, 255)})$ of white, the values $X_{(255, 0, 0)}, Y_{(255, 0,}$

$_{0)}$, $Z_{(255, 0, 0)}$), ($X_{(0, 255, 0)}$, $Y_{(0, 255, 0)}$, $Z_{(0, 255, 0)}$) and ($X_{(0, 0, 255)}$, $Y_{(0, 0, 255)}$, $Z_{(0, 0, 255)}$) of red, green and blue, respectively, and the color tone characteristics $fR(r)$, $fG(g)$ and $fB(b)$ of red, green and blue, respectively

5 (see Fig. 3). Since a matrix profile assumes that the above equation holds true, high accuracy can be obtained in the case of a device with both a high color additive-mixture and a high degree to which a color tone characteristic can be approximated by a relation

10 f (approximation characteristic) (for example, a CRT). However, only low accuracy can be obtained in the case of the other devices (for example, a printer or the like). Even displays have different color additive-mixture characteristics and the

15 approximation characteristics of a color tone characteristic vary depending on their types and models. Generally speaking, a CRT has high color additive -mixture and approximation characteristics, and an LCD or PDP has lower color additive-mixture and

20 approximation characteristics than a CRT.

An LUT profile stores an LUT (look-up table) for converting an input value into an output value. The profile divides the space of an input value (for example, RGB values) into nxnxn grid data, and stores the output

25 values of the grid points (CIELAB) as data. Similarly,

an LUT for inverse conversion divides the space of an output value into m×m×m grid data and stores these input values as data. These division numbers n and m are called a "number of grids" or "grid". The numbers of grids
5 n and m are usually 9, 17 and 33, which are all "prime numbers of 8 bits (256) + 1". An ICC profile stores an LUT using 8-bit or 16-bit values. Since an ICC profile stores all correspondences between input and output using an LUT, an ICC profile has a greater size than
10 a matrix profile.

The color-matching module (CMM) of a CMS converts color using an LUT. If an input value is on a grid, the CMM calculates an LUT value. If an input value is not on a grid, the CMM calculates an output value by
15 interpolating a value in the neighborhood. The correspondence between input and output is 1 to 1, and is common to all devices. The LUT profile is not limited to use in a display and can be used in all color input/output devices.
20 To generate a display profile with high-accuracy, the following problems must be solved.
1.Color stability immediately after display

In the case of a display, displayed color is in a transient state for a period immediately after display
25 and then shifts to a static state. Since a measurement

value in a transient state is a peculiar value, which is not the characteristic value of a display, measurement must be conducted in a static state.

2.Afterimage of displayed color

5   If another color is displayed after a specific color is displayed, sometimes the previous color affects a subsequent color. The influence of the previous color causes an error between a measurement value and the characteristic of a display.

10 3.Stability at the time of the start of a display

Color on a display is in a transient state for a period immediately after the power of the display is switched on and enters a static state after several minutes to several tens of minutes. Fig. 4 shows the

15 fluctuation characteristics of display luminance after the power is switched on. Fig. 4 shows an example of the luminance fluctuations immediately after the power of a CRT is switched on and which are shown in an international regulation draft IEC-61966-3, which

20 the IEC (International Electro-technical Commission) is currently working on. The display measurement must be conducted in a static state. The period required for color to enter a static state (time constant) varies depending on the models and types of displays.

25 4.Display in which display luminance fluctuates

Some models of displays change the amount of power applied to the displays depending on color or areas to be displayed in order to suppress power consumption. Fig. 5 is a graph for showing an example of a relationship

5   between a display area and luminance. If such a display is measured without any correction, sometimes the measurement value of blue becomes brighter than that of white. Since the measurement of a display characteristic must always be conducted under the same

10 conditions, an accurate profile cannot be generated from such a measurement result.

5.Measurement error

A user must always monitor measurement situations so that an unexpected error cannot occur,

15 for example, so that a measuring instrument does not malfunction during measurement or so that extraneous light is not measured.

6.Information amount of a matrix profile

A matrix profile stores the color tone data of

20 R, G, B or the like. The greater the number of color tones, the more accurate a profile becomes. However, the size of a profile increases in proportion to the number. The necessary information amount in a profile varies depending on the display.

25 7.Number   of   tone   reproduction   characteristic

measurements

A matrix profile stores the color tone data of R, G, B or the like. In proportion to the number of color tones to be stored, the number of measurements

5   increases and the period required to generate a profile increases.

8.Accuracy of the information of a profile

In a profile regulated by ICC, measurement values are stored as a ratio to white. As a result, even

10   measurement values with different display luminance are stored as the same color if their ratios to white are the same. However, as known by the Betzolt-Brücke phenomenon or the like, color appearance changes as light intensity increases. It is known that human beings

15   recognize such colors to be different. Since the color appearance of a specific color with a specific relative measurement value against white varies depending on light intensity, high-accuracy color matching cannot be expected.

20   9.Problems with both display setting and profile generation

The color temperature and γ characteristic of some current displays and display cards can be changed. With such a model, a user can set the color temperature

25   and γ characteristic. Since the display characteristic

of a display varies depending on the color temperature setting and γ characteristic setting, a profile must be generated for each setting.

10. Number of grids of an LUT profile

5   An LUT profile stores the grid data of R, G, B or the like as a look-up table (LUT). The larger the number of grids, the more accurate a profile becomes. However, a profile size increases in proportion to the number. The necessary information amount in a profile

10 varies depending on the display.

11. Number of grid data measurements

     An LUT profile stores the LUTs of R, G, B or the like. In proportion to the number of grids to be stored, the number of measurements increases and thereby the

15 period required to generate a profile increases. Since a matrix profile stores color tone data, it is sufficient for a matrix profile to measure at most 759 colors (256 color tones for each of R, G and B and one white color (255, 255, 255)). Whereas, an LUT profile

20 must measure at most 16,770,000 colors (256x256x256 colors). Even an LUT with 10 grids must measure 1,000 colors. To generate a profile with high accuracy by using many grids, a huge amount of measurements must be conducted.

25 12. Selection of a profile type

There are two types of profiles: a matrix profile for storing both color tone values and the color information of R, G and B and an LUT profile for storing tables for color conversion. Although the accuracy of

5 a matrix profile is low except for a model in which the display characteristic of a display is pre-determined, the file size is very small (approximately 1kB). Whereas, although the file size of an LUT profile is large (50kB to 300kB), the LUT

10 profile can be used for any display (LCD and PDP display devices or the like). The profile, which should be used, varies depending on the types and models of displays.
13.Confirmation of profile accuracy

Even if a profile is generated, a user cannot

15 confirm the adequacy of the profile on the spot.

summary of the Invention

An object of the present invention is to provide both a high-accuracy profile generating method and a

20 display characteristic measuring method needed for color matching.

According to the present invention, to avoid an unstable display, immediately after a color patch is displayed, the color patch starts to be measured at

25 a specific time after the color patch is displayed.

Alternatively, a color patch can be measured a plurality of times and one measured after a measurement value is stabilized can be used as a correct measurement value.

5   By displaying and measuring a color patch at a specific time after the previous color patch disappears and before the display of a color patch to be measured, the afterimage of the previous color patch can be prevented from causing an error in a measurement value.

10   Displaying and measuring a color patch at a specific time after the start-up of a display can avoid the instability of the display at the time of start-up.

If the luminance of a display is changed in order to suppress power consumption, color patchs of

15   different sizes are sequentially displayed and measured, and a color patch of the size, which has been measured when a measurement value is stabilized, is used.

If extraneous light has been measured by mistake,

20   a measurement error can be detected by checking for a gap among measurement values.

Both the information amount of a matrix profile and the number of color tone characteristic measurements can be optimized by generating profiles

25   with different information amounts and a different

set.

Fig. 8 is a flowchart showing the process in the case where the error of a color patch measurement value is reduced due to afterimage at display intervals of color patchs.

Fig. 9 is a flowchart showing the process in the case where color patch display intervals are automatically set.

Fig. 10 shows one γ curve.

Fig. 11 shows a γ curve based on a model of equation (2).

Fig. 12 is a flowchart showing the color patch measuring process of a display, the power consumption of which is variable.

Fig. 13 shows a relationship between the number of nodes of a TRC and accuracy.

Fig. 14 is a flowchart showing the process of generating a profile for storing a TRC or a γ coefficient value.

Fig. 15 shows the color tone characteristic of γ1.8.

Fig. 16 is a flowchart showing the process of updating a profile by measurement.

Fig. 17 is a flowchart showing the process of generating an LUT profile using a color additive

-mixture characteristic.

.Fig. 18 shows the configuration of the first preferred embodiment of the display-measuring device of the present invention.

5   Fig. 19 shows the configuration of the second preferred embodiment of the display-measuring device of the present invention.

Fig. 20 shows the configuration of the third preferred embodiment of the display-measuring device

10   of the present invention.

Fig. 21 shows the configuration of the fourth preferred embodiment of the display-measuring device of the present invention.

Fig. 22 shows the configuration of the fifth

15   preferred embodiment of the display-measuring device of the present invention.

Fig. 23 shows the configuration of the sixth preferred embodiment of the display-measuring device of the present invention.

20   Fig. 24 shows the configuration of the seventh preferred embodiment of the display-measuring device of the present invention.

Fig. 25 shows the configuration of the eighth preferred embodiment of the display-measuring device

25   of the present invention.

Fig. 26 shows a relationship between the number of nodes of a TRC and the accuracy of a profile generated by the TRC.

Fig. 27 shows one γ characteristic of a display.

5   Fig. 28 shows the dump code of a matrix profile.

Fig. 29 shows the detailed configuration of the eighth preferred embodiment of the display-measuring device shown in Fig. 25.

Fig. 30 shows the configuration of the ninth 10 preferred embodiment of the display-measuring device of the present invention.

Fig. 31 shows the detailed configuration of the ninth preferred embodiment of the display-measuring device shown in Fig. 30.

15   Fig. 32 shows the configuration of the tenth preferred embodiment of the display-measuring device of the present invention.

Fig. 33 shows the configuration of the eleventh preferred embodiment of the display-measuring device 20 of the present invention.

Fig. 34 shows the configuration of the twelfth preferred embodiment of the display-measuring device of the present invention.

Fig. 35 shows the configuration of an alternative 25 of the twelfth preferred embodiment in which a human

being makes the judgment of a comparison control unit.

Description of the Preferred Embodiment

The first problem can be solved by a display
5   measuring method comprising the steps of displaying
one or a plurality of color patchs, counting a time
that elapses after displaying the color patchs and
measuring the color of the color patchs displayed on
a display.

10   The second problem can be solved by a display
measuring method comprising the steps of displaying
one or a plurality of color patchs, measuring the color
of the color patchs displayed on a display, displaying
a pre-determined image after the measurement and
15   counting a time that elapses after displaying the image.

The third problem can be solved by a display
measuring method comprising the steps of displaying
a pre-determined specific image (color patch) before
the measurement of all color patchs, counting a time
20   that elapses after displaying the image, displaying
one or a plurality of color patchs and measuring the
color of the color patchs displayed on the display.

The fourth problem can be solved by a display
measuring method comprising the steps of displaying
25   both a color patch of a standard size composed of the

same color and a color patch of a fairly small size, measuring the respective color patchs, reducing the reference size if the measurement values of the respective color patchs are different and setting the

5   reference size as the size of the respective color patchs if the measurement values of the respective color patchs are the same.

The fifth problem can be solved by a display measuring method comprising the steps of measuring the

10   color of color patchs displayed on a display, comparing the RGB values of a color patch measured before with the RGB values of the current color patch and comparing the respective results in the color patch RGB value comparison step and measurement value comparison step.

15   The sixth problem can be solved by a profile generating method comprising the steps of measuring the color tone values of a display, generating a plurality of TRCs , on which the values of a plurality of tone reproduction curves (γ curves) at discrete

20   points are recorded with different numbers of color tones based on measured color tone data, verifying the accuracy of a profile based on the TRC generated in the TRC generation step and generating a profile using a TRC with the highest accuracy.

25   The seventh problem can be solved by a profile

generating method comprising the steps of measuring at least two colorless color patchs, detecting dispersion in the measurement values of the colorless images based on the measurement result in the colorless

5　measurement step, comparing the dispersion value calculated in the dispersion calculation step with a predetermined threshold value and measuring the color tone value of a display.

The eighth problem can be solved by a profile

10　generating method comprising the steps of storing reference data used to convert measurement data, converting a measurement value using the reference value and generating a profile using the converted measurement value. The reference value used to convert

15　the measurement data is stored in the generated profile.

The ninth problem can be solved by a profile generating method comprising the steps of measuring a color patch displayed on a display, generating a plurality of LUTs with different numbers of grids based

20　on measured grid data, verifying the accuracy of a profile based on the LUTs generated in the LUT preparation step and generating a profile using an LUT with the highest accuracy.

The tenth problem can be solved by a profile

25　generating method comprising the steps of measuring

a color patch displayed on a display, generating a plurality of LUTs with different numbers of grids based on measured grid data, verifying the accuracy of a profile based on the LUTs generated in the LUT

5   preparation step and generating a profile using an LUT with the highest accuracy.

The eleventh problem can be solved by a profile generating method comprising the steps of displaying the color patch of color tone data on a display,

10   measuring the color patch displayed on the display, generating grid data from the measurement value of the color tone data of R, G and B color elements by color additive -mixture and generating a profile from the grid data.

15   The twelfth problem can be solved by a profile generating method comprising the steps of measuring a color patch displayed on a display, generating a matrix profile, generating an LUT profile, calculating the accuracy of the generated matrix profile and

20   selecting either the matrix or LUT profile.

The thirteenth problem can be solved by a profile accuracy verifying method comprising the steps of designating a profile, displaying a color patch for accuracy verification, measuring the color patch for

25   accuracy verification, comparing a value calculated

using the designated profile with the measurement result of the color patch for accuracy verification and verifying the accuracy of the profile based on the comparison result.

5   Since the color immediately after display is not stable, this measurement value does not correctly display a display characteristic (problem 1). The color immediately after display enters a normal state after a specific period of time in a transient state. By

10   measuring in a normal state instead of in a transient state, the first problem can be avoided. To do so, it is better to set a time interval (measurement interval) between the display of a color patch and the start of measurement.

15   Fig. 6 is a flowchart showing the process of solving the first problem.

First, in step S1, a color patch is displayed on a display. Then, in step S2, a specific time is counted. After a specific time elapses, the color patch is

20   measured (step S3), and in step S4 it is judged whether the process should be finished. If the process is not finished, the flow returns to step S1 and the processes are repeated. If the process is finished, the measurement is finished. A specific time (measurement

25   interval) should be appropriately set depending on the

model of the display or the like.

A measurement interval can be individually set depending on the model used by a user, by a user designating the model.

5   A time required for the color of a displayed slip to shift from a transient state to a normal state (time constant) can be largely classified depending on model. Generally speaking, the time constant of a CRT is short and that of an LCD or PDP is long. A measurement interval,

10   which is pre-determined for each model of a display to be used, can also be adopted. This time constant sometimes varies depending on color patchs. The brighter a color patch, the longer the time constant. The darker a color patch, the shorter the time constant.

15   In such a display, a measurement interval suitable for a color patch can be determined by increasing/decreasing the measurement interval depending on color patchs. Alternatively, a table of measurement intervals can also be generated in advance.

20   Alternatively, a measurement interval can be automatically calculated.

Fig. 7 is a flowchart showing the process of automatically setting a measurement interval.

First, in step S5 a color patch is displayed,

25   and in step S6 the color patch is measured. In step

S7, the measurement value of the previous color patch is compared with the measurement value of the current color patch and it is judged whether a measurement value is stabilized (the fluctuations of a measurement value

5 remain below a specific threshold value). If a measurement value is not stabilized, the flow returns to step S6 and the color patch is measured again. If a measurement value is stabilized, in step S8 it is judged whether the measurement is finished. If there

10 is no measurement value, the flow returns to step S5 and the measurement is continued.

In this case, the color patch is consecutively measured after the color patch display. If the current measurement result is significantly different from the

15 previous result, the color is considered to be in a transient state. If the fluctuations diminish, the color can be considered to be in a normal state. If it is judged that the color is in a normal state, the measurement value of the color patch is stored. A period

20 judged to be required for the color to enter a normal state after the color patch display in the first measurement is stored as a measurement interval. By using the result of the first measurement as a measurement interval for the second and subsequent

25 measurements, a normal state judgment process can also

be skipped for the second and subsequent measurements.
If a time required for the color to enter a normal state
varies depending on color patchs, a measurement
interval can be increased/decreased depending on the
5   values of color patchs using the first measurement
result as the reference.

If, for example, blue (0, 0, 255) is displayed
following red (R, G, B) = (255, 0, 0) on some display,
sometimes there will be a slight shine to the color
10   although the pixel of R is "0" (there is no voltage
on the pixel of R). In such a display, for example,
the measurement value of blue (0, 0, 255) obtained
following black (0, 0, 0) is different from that of
blue (0, 0, 255) obtained following red (255, 0, 0).
15   In other words, the color to be displayed varies
depending on colors displayed immediately before
(problem 2). The phenomenon in which the color displayed
immediately before remains on a display even after
finishing the display, is called an "after-image". When
20   there is an after-image, it is acceptable if a specific
image is displayed for a specific period (color patch
display interval) after displaying and measuring a
color patch, and a subsequent color patch is displayed
when there is no after-image. The specific image
25   displayed in this case is a color with no after-image,

that is, a color patch of black (0, 0, 0), and by displaying and measuring a subsequent color patch after a specific time elapses, measurement without the influence of an after-image can be made possible.

5   Alternatively, a color display interval can be individually set for each color previously displayed. Furthermore, a time required to enter no after-image state can be largely classified depending on models. Generally speaking, in the case of a CRT, the period

10   is short; and in the case of a PDP, the period is long. Alternatively, a color display interval pre-determined for each model to be used can be used. Sometimes the continuation time of an after-image varies depending on color patchs. The lighter a color

15   patch, the longer the time, and the darker a color patch, the shorter the time. In such a display, a color display interval suitable for a color patch can be used by setting a different color display interval for each color patch or increasing/decreasing a color display

20   interval depending on the color patchs. Alternatively, a color display interval can be automatically calculated.

     Fig. 8 is a flowchart showing the process of reducing the error of a color patch measurement value

25   due to an after-image by a color display interval.

First, in step S10 a color patch is displayed, and in step S11 the color patch is measured after the display enters a normal state. Then, in step S12 a specific time (color display interval) is counted after

5   displaying a specific image, and in step S13 it is judged whether the measurement is finished. If the measurement should be continued, the flow returns to step S10. Then, another color patch is displayed and the process is continued. Otherwise, the process is terminated.

10   Fig. 9 is a flowchart showing the process of automatically setting a color display interval.

In step S15 a color patch is displayed and in step S16 the color patch is measured. In step S17, a previous color patch measurement value and a current

15   color patch measurement value are compared and it is judged whether a measurement value is stabilized. If the value is stabilized, in step S18 it is judged whether the measurement is finished since it means that there no longer is an after-image. If the measurement value

20   is not stabilized, the flow returns to step S16 and the color patch is measured again since it means that there is still an after-image. If in step S18 it is judged that the measurement should not be stopped, the flow returns to step S15 and a subsequent color patch

25   is displayed.

If there are still large fluctuations when the measurements are compared, it can be judged that an after-image still remains. If there are no fluctuations, it is judged that there no longer is an after-image.

5   If it is judged that there is no after-image, a subsequent color patch is displayed. As to the measurement of fluctuations, alternatively, first, a black image can be measured as a reference and the measurement result can be stored as a reference value.

10 By measuring a black color patch and comparing the measurement value with the reference value, it can be judged whether there are fluctuations. In this case, a time required to judge whether there is an after-image after the color patch measurement is stored as a color

15 display interval, and the process of judging whether there is an after-image can be skipped in the second and subsequent measurements by using the first measurement result for the second and subsequent measurements. If a period required to enter a normal

20 state varies depending on color patchs, it is acceptable if the time is increased/decreased depending on the value of color patchs using the first measurement result as the reference value.

The display on a display is stabilized for a period

25 after the power is switched on (problem 3). By

displaying a specific image after the power of the display is switched on, displaying a color patch for a specific time (measurement start interval) after the display is switched on and starting the measurement

5 of the color patch, measurement can be started in the stable state of the display. It is sufficient if a measurement start interval can be used only for the first measurement. Alternatively, by enabling a user to designate a measurement start interval, the

10 measurement start interval can be individually set depending on a model used by a user. Furthermore, a period required to enter a normal state can be largely classified depending on models. Generally speaking, in the case of a CRT, the time is short, and in the

15 case of a PDP, the time is long. Therefore, a color patch display interval pre-determined for each display model to be used can also be used.

It is known that a tone reproduction characteristic of a display can be approximated by a

20 curve called a γ curve. Fig. 10 shows one γ curve. A display with the tone reproduction characteristic shown in Fig. 10 can be expressed as follows.

$$(\text{Output}) = (\text{Input})^{\gamma} \qquad (\gamma=2.2) \qquad (1)$$

In this case, this display is called a "display

25 of γ (gamma) 2.2". There are also a display with a bright

background and a display with a steeper rising input /output curve. The models of such displays cannot be expressed simply. They must be expressed by the following more complex equations.

5   (Output) = a (Input + b)$^\gamma$ + c   (2)

     (γ=2.2, a=1.5, b=1.8 and C-2.3)

Fig. 11 shows a γ curve according to a model expressed by equation (2). A matrix profile targets a model according to equation (1) and does not target other

10   complex models. Therefore, sufficient color matching accuracy cannot be expected of a profile generated from the measurement value of a display of such a model. For example, the following complex models, in addition to model (1), can be generated, the relevant model can

15   be judged based on the measurement results and the model of the relevant display can be judged by calculating the respective parameters.

     Output = (Input)$^\gamma$ + c   (3)

     Output = a (Input)$^\gamma$ + c   (4)

20   Output = a (Input+b)$^\gamma$ + c   (5)

By storing those parameters in a profile, color matching with higher accuracy can be implemented in CMSs corresponding to models (3) through (5) than in a CMS corresponding to only the conventional model (1).

25   Some displays perform control of voltage applied

to a display panel depending on colors to be displayed or areas to be displayed for the reason that power consumption must be suppressed below a specific value or the like (problem 4). In the current display, in

5 particular, in a PDP with large power consumption, such a method is popular. Such a function is designed to operate if the consumption power of a display exceeds a specific value. Therefore, if the display area of a color patch is small, the power control does not

10 function.

Fig. 12 is a flowchart showing a color patch measuring process in a display with variable power consumption.

First, in step S20 a color patch is displayed

15 and in step S21 the color patch is measured. Then, in step S22 a color patch with a smaller size than the measured chip is displayed, and in step S23 the color patch with the smaller size is measured. In step S24 it is judged whether the difference in a measurement

20 value between color patchs measured in steps S21 and 23 is equal to or less than a threshold value. If the difference is judged to be equal to or less than the threshold value, it is not considered that power control has not been performed and in step S25 a color patch

25 size is set to the color patch size set in step S22.

If in step S24 it is judged that the difference of the measurement value is more than the threshold value, it is considered that power control has been performed, the flow returns to step S22 and a far smaller color
5   patch is processed. Individual users should appropriately determine the threshold value.

Thus, a color patch of a pre-determined size is measured and then a smaller color patch is measured. If the two measurement results are different, it is
10   detected that power control has been performed. In this case, the measurement of a smaller color patch is repeated. If the measurement results become the same, it is detected that power control has not been performed for the size, the color patch size is set to the size
15   and the color is displayed. If white is displayed, the respective R, G and B pixels radiate at a maximum intensity. Since power consumption becomes a maximum if white is displayed, white (255, 255, 255) is preferable as the color of a color patch to be used
20   to detect a size in which power control is not performed. If a size in which power control is not performed is determined, the size can also be stored and this stored size can also be used for the second and subsequent measurements.

25   If there is an error for some reason when a display

is measured, it is difficult for a user to detect the error (problem 5). It is natural that high-accuracy color matching cannot be expected of a profile generated from a measured result with an error. Therefore, the

5   existence/non-existence of an error during measurement must be detected. The error of a measurement value can be detected by judging whether a color additive-mixture can be applied. Alternatively, there is a correlation between a measurement color value (XYZ

10   values) and a color patch value (RGB values). Generally, the greater the RGB values, the greater the CIEXYZ values. Therefore, the difference between measurement values can be detected by judging whether XYZ values increase /decrease as RGB values increase/decrease.

15   Since color additive-mixture can be applied in a display, the measurement value of white (255, 255, 255) is the greatest of those of all colors. Therefore, the existence/non-existence of the difference between measurement values can be detected by judging whether

20   the result of white is the greatest. The measurement of white can be conducted first, the measurement value can be stored and the value can be compared with the second and subsequent measurement values. Alternatively, the measurement result of white can be

25   compared with that of another color after the

measurement is finished. In this case, comparison can be conducted for all the elements of a measurement value (for example, an X value, a Y value and a Z value in the case of CIEXYZ values) or for only one of the

5   elements. A color to be used for comparison is not limited to white, and an arbitrary color can be used.

If an error is detected in such a check stage of a measurement value, a WARNING message is issued. It is preferable to notify a measurer of the error by

10   making a BEEP sound or the like. Upon receipt of the message, the measurer checks whether a measuring instrument is disconnected, whether extraneous light penetrates or the like, and the measurement error can be immediately handled.

15   In a matrix profile, the respective color tone values of R, G and B can be stored in a form of a TRC. A TRC is expressed as a value in the range of 0 to 65535, with 65535 and 0 as the maximum and minimum values, respectively. Since, as the number of nodes expressing

20   a TRC increases, the profile size increases in proportion to the increase. Therefore, it is preferable to generate a profile in which high accuracy can be obtained by even the small number of nodes in a TRC (problem 7). By generating several TRCs with different

25   numbers of nodes based on the measurement results of

R, G and B values, by calculating color reproduction
accuracy in the case of each TRC and by storing a TRC
with the highest accuracy in a profile, a profile with
the highest accuracy can be generated. Fig. 13 shows
5   a relationship between the number of nodes of a TRC
and accuracy. In the case of a CRT, the number of nodes
of a TRC does not improve accuracy any more after the
number reaches a specific number. If the number of nodes
of a TRC is increased, accuracy becomes higher. However,
10   the file size also increases in proportion to the
increase in the number of nodes of a TRC. Therefore,
it is preferable to set the number of nodes of a TRC
to about 16 in such a display since the improvement
of accuracy becomes saturated at a specific point. By
15   comparing accuracy corresponding to the number of nodes
of a TRC with a file size and selecting the most effective
number of nodes of a TRC, the highest performance can
be introduced even in a small profile size. As to a
matrix profile, there is also a method for storing a
20   γ coefficient value instead of a TRC, on which a numeric
value at each discrete point of a γ curve is recorded.
If the tone reproduction characteristic of a display
can be obtained and a relationship between an input
and an output can be approximated by $(Output) = (Input)^{\gamma}$,
25   a γ coefficient value can be stored instead of a TRC.

Fig. 14 is a flowchart showing the profile generation process of storing a TRC or a γ coefficient value.

First, in step S30, a color patch in a specific

5 color is displayed. In step S31 the color patch is measured, and in step S32 it is judged whether the measurement of all color clips in appropriate colors is finished. If the measurement is not finished, the flow returns to step S30 and the measurement is

10 continued. If the measurement is finished, the flow proceeds to step S33 and a γ coefficient value is calculated from a TRC. Then, in step S34 the accuracy of an input/output relationship is calculated based on the calculated γ coefficient value, and in step S35

15 it is judged whether the error between the input/output relationship based on the calculated γ coefficient value and a measurement result is equal to or less than a threshold value. If the error is equal to or less than the threshold value, the accuracy of a profile

20 using the γ coefficient value is judged to be high. Therefore, in step S37 a profile that stores a γ coefficient value is generated. If in step S35 it is judged that the error is more than the threshold value, the input/output relationship obtained by the

25 calculated γ coefficient value does not have sufficient

accuracy. Therefore, in step S36 a profile that stores
a TRC is generated and the process is terminated.

The optimal number of nodes of a TRC varies
depending on the types of display (problem 6). Therefore,

5   the optimal number of nodes of a TRC for each type (or
model) of display can also be generated and can also
be selected according to the type (or model). Although
an ICC profile stores TRCs for each R, G and B color
element, the profile does not always need to store

10   measured TRCs for each R, G and B color element.
Alternatively, a TRC can be generated by measuring the
color tone data of white and the data can be stored
as a TRC with R, G and B color elements. In particular,
in the case of a CRT, there is almost no difference

15   in a tone reproduction characteristic between red,
green and blue color elements. Whether the tone
reproduction characteristics of red, green and blue
color elements are the same can be judged by measuring
an intermediate tone color (gray). Specifically, if

20   the tone reproduction characteristics of red, green
and blue are the same, all the chromaticity values of
gray are the same. In the case of a display with scattered
color tones, for example, if the γ coefficient value
of blue is smaller than that of red or green, the lighter

25   dark gray becomes, the more bluish it becomes, and when

it goes beyond a specific point, it becomes whitish. The chromaticity values of gray, which is an intermediate tone color, and white are measured. If there is no difference in the chromaticity values of

5   gray and white, a TRC is generated from the color tone data of white or one of red, green and blue, and is stored as the TRC of red, green or blue. Thus, the number of times the measurement is required can be reduced. If there is a difference in the chromaticity values

10   of gray, which is an intermediate color, and white, a tone reproduction characteristic must be obtained for each color and a TRC must be generated for each color.

     Although in an ICC profile, the measurement value

15   of a color patch is stored in a form of a ratio to a reference color (D50), color appearance also varies depending on light strength (Betzolt-Brücke phenomenon: problem 8). The numeric value of a profile can be uniquely determined by setting in advance a color,

20   which will be a reference, modifying the measurement data based on the measurement value of the reference color, generating a profile based on the result and also storing the reference value in the profile. Alternatively, the measurement value itself can also

25   be stored. By using such a profile, a CMS in which a

difference in color appearance due to the Betzolt-Brücke phenomenon is taken into consideration can be implemented.

There are some current display devices, the display characteristics of which can be changed by a display, a display card, an OS or the like. Since the profile of a display varies depending on the display characteristics of a display, a profile must be generated after measuring the display characteristic of each display (problem 9). However, if a tone reproduction characteristic varies, the R, G, B and W values do not vary, and only a TRC varies. Similarly, if color temperature varies, the TRC does not vary, and only the R, G, B and W values vary. Therefore, modifying only a TRC without measurement based on a measured and generated profile can generate a profile, only the tone reproduction characteristic of which varies. Similarly, modifying only the R, G, B and W values without measurement based on a measured and generated profile when color temperature is modified can generate a profile with a different color temperature. The display characteristic of a display is determined not only by a single display, but also by a combination of display cards or the like. Therefore, even if a display card is set to γ 2.2, there is no

guarantee that the display is really set to γ2.2. One display is set to γ1.8, and another display is set to γ2.9. The same description applies to color temperature. Even if 9300K is set for a display, the color temperature

5   of one display card is more than 10,000K and that of another display card is about 8,000K. In such a case, color temperature must be actually measured and the measurement result must be stored. However, the complete measurement is not required. The tone

10   reproduction characteristic of a display can be approximated by (Output) = (Input)$^{\gamma}$. Therefore, if a point N (N≥2) on a tone reproduction curve is obtained, γ can be calculated.

Fig. 15 shows a γ characteristic, and Fig. 16

15   is a flowchart showing the process.

In step S40 of Fig. 16 a basic profile is designated, and in step S41 a color patch at an intermediate point on a tone reproduction curve is measured. Then, in step S42, a TRC or a γ coefficient

20   value is calculated. Then, in step S43 the TRC part or γ coefficient value part of the profile is updated and the process is terminated.

If the luminance of the measurement value of white (255, 255, 255) and the luminance of gray (128, 128,

25   128) are assumed to be 100cd/m^2 and 28. 7cd/m^2,

respectively, the luminance ratio of gray to white is 0.287. Since the RGB values of white and gray are (255, 255, 255) and (128, 128, 128), the RGB value ratio of gray to white is 0.502. If the ratios are assigned to

5 the equation (Output) = (Input)$^\gamma$, 0.287 =0.502$^\gamma$, and γ=1.8 can be obtained. By generating a TRC based on γ=1.8 and storing γ=1.8 in the profile, a profile with high accuracy can be generated with a small number of measurements. Although only one intermediate point is

10 sufficient, by increasing the number of intermediate points, for example, to up to two or three points, and by measuring the points, a more accurate TRC or γ coefficient value can be calculated. Similarly, as to color temperature, only one color, white, is measured,

15 and R, G, B and W values to be stored in a profile can be calculated based on the measurement value. If the calculated result is stored in a profile, measuring only one color can generate a profile with accurate color temperature.

20 An LUT profile stores outputs against inputs in a form of an LUT (look-up table). Since R, G and B values are 8 bits, a profile with the highest accuracy can be generated if 256×256×256 LUTs, each of which is called a 256-grid LUT, are stored. However, a 256-grid LUT

25 must store 16,000,000 pieces of data, which is not

practical (problem 10). In reality, a small number of grids, such as 8 grids or 10 grids are stored, and parts without data are interpolated by neighboring information (grid points). As in the case of a TRC,

5   by generating a plurality of LUTs with different numbers of grids based on measurement data, calculating the accuracy of each LUT and generating a profile using an LUT with the highest accuracy, a profile with high accuracy can be generated. As in the case of a matrix

10   profile, in an LUT profile, when the number of grids exceeds a specific value, accuracy cannot be improved any more. However, a profile size increases in proportion to the cube of the number of grids. By determining the number of an LUT, taking into

15   consideration both a profile size and LUT accuracy, a more efficient LUT profile can be generated.

The relationship between the number of LUTs and accuracy depends on the models (types) of a display. For example, in the case of a CRT, high accuracy can

20   also be obtained despite a small number of grids. Alternatively, the number of grids can be selected depending on display types.

Since a matrix profile stores color tone data, it is sufficient if the maximum of 769 colors (a highly

25   accurate profile of 256 color tones for each of R, G

and B and one color of white (255, 255, 255)) are measured.
However, in the case of an LUT profile, the maximum
of 16,770, 000 colors or more (256×256×256 colors) must
be measured (problem 11). Even in the case of a 10-grid
5   LUT, 1,000 colors must be measured. To generate a
profile with high accuracy in the case of a large number
of grids, an enormous number of measurements must be
conducted. In the case of a display, if the measurement
value of grid data is calculated by color additive
10   mixture, an LUT profile with a large number of grids
can be generated by a small number of measurements.
For example, even if an LUT profile with 9 grids is
generated, the number of measurements can be reduced
from 729 (9^3) colors to 28 (3×9 + 1) colors. However,
15   some displays have both low color additive mixture
accuracy   and   a   big   error   between   a   color
additive-mixture calculation value and a measurement
value due to the influence of a shining black display,
or the like. In such a display, if a measurement value
20   is calculated by color additive-mixture, profile
accuracy degrades. In such a case, color additive-
mixture accuracy can be confirmed in advance. In the
case of a display with high color additive-mixture
accuracy a color tone value can be measured and grid
25   data can be generated by color additive-mixture. In

the case of a display with low color additive-mixture
accuracy, grid data can be measured.

Fig. 17 is a flowchart showing the process of
generating an LUT profile utilizing a color additive

5   -mixture characteristic.

First, in step S45, a color patch in a primary
color is displayed. Then, in step S46 the color patch
is measured, and in step S47 it is judged whether all
color patchs are measured. If all color patchs are not

10   measured yet, the flow returns to step S45 and a
subsequent color patch is measured. If in step S47 it
is judged that all color patchs are measured, in step
S48 secondary and tertiary colors are calculated by
color additive-mixture. Then, in step S47 an LUT grid

15   is generated. Then, in step S50 a profile is generated
and the process is terminated.

By switching data to be measured depending on
color additive-mixture accuracy, only in the case of
a display with high color additive-mixture accuracy,

20   an accurate profile can be generated with a small number
of measurements. In the case of a display with low color
additive-mixture accuracy, there is no degradation of
profile accuracy since grid data are measured.
Alternatively, grid data can be generated using both

25   color tone data and grid data instead of only by the

color additive-mixture of color tone data. For example,
if the measurement data of 17-grids is generated using
color tone data of 17 color tones, more accurate grid
data can be generated by correcting a color
5   additive-mixture value using the result of the
measurement data of 5 grids. Even in this case, if grid
data are generated from a measurement value, the
measurement of only 175 colors (50 colors in 17 color
tones + 125 colors on 5 grids) is sufficient, although
10 the measurement of 4,913 colors is recommended.

There are a matrix profile and an LUT profile
in a display profile. In some displays, a matrix profile
has higher accuracy than an LUT profile, while in other
displays, an LUT profile has higher accuracy than a
15 matrix profile (problem 12). Therefore, by generating
both an LUT profile and a matrix profile when generating
a profile, calculating the accuracy of each profile
and selecting only the more accurate profile, a user
can always obtain the more accurate profile without
20 selecting a profile type.

If the color additive-mixture accuracy of a
display is high, the accuracy of a matrix profile is
higher than that of an LUT profile and also the file
size of a matrix profile is smaller than that of an
25 LUT profile. Since the color additive-mixture accuracy

of a current display, in particular, a CRT, is high, the accuracy of a matrix profile is higher than that of an LUT profile. The number of measurements required to generate an LUT profile is greater than that of a

5   matrix profile. Therefore, alternatively, first, a matrix profile can be generated and the accuracy can be judged. If the accuracy is equal to or less than a pre-determined accuracy, it can be judged that the display has low color additive-mixture accuracy, an

10 LUT profile can be generated, the accuracy of the LUT profile can be compared with that of the matrix profile again and a profile with higher accuracy can be selected. The accuracy of each profile varies depending on the types (or models) of a display. Therefore,

15 alternatively, a profile type to be generated can be set in advance for each type of a display and a profile type can be selected according to the type of a display.

If a user generates a profile, the user cannot verify the accuracy of the profile on the spot (problem

20 13). However, by measuring a display, the user can verify the accuracy of a display profile. By comparing a measurement result obtained by measuring a color patch for accuracy verification with an output value obtained by passing the color patch for verification through

25 a profile as an input value, accuracy can be confirmed.

By using a real image, the accuracy of a profile can be more directly confirmed. By using a profile, a CMS can convert an input value (for example, RGB values) into a common color signal (for example, CIELAB

5   values) or can inversely convert a common color signal into RGB values. In this case, an image is converted into a common color signal using a generated profile and is inversely converted using the same profile. In this case, since color is converted using the same

10   profile, an input image must be the same as an output image. In reality, their values are different due to an operation error or a rounding error. Therefore, both the input and output images are displayed on a display (or printed on a piece of paper) and are compared. If

15   the accuracy of a profile is low, the color of the output image is different from that of the input image. If a difference between the input and output images cannot be recognized, it can be judged that the accuracy of the profile is high. By combining such a verification

20   of a profile with a profile generation, the possibility of using a profile with low accuracy can be reduced. By confirming the accuracy of a profile generated by conducting   measurement   for   evaluation   after generating a profile or confirming the difference

25   between input and output images by converting the images

using a profile generated after generating the profile, the accuracy of the profile can be verified.

Fig. 18 shows the configuration of the first preferred embodiment of the display-measuring device
5   of the present invention.

A color patch storage unit 100 stores a color patch required to measure the characteristic of a display. A color patch display unit 101 (for example, a frame buffer) receives color patch data and
10   plots/displays a color patch on a display. After displaying the color patch, the color display unit 101 transmits a color patch display signal to a timer 102. The timer 102 counts for a specific time after receiving the color patch display signal and transmit a trigger
15   signal to a measurement control unit 103 after the specific period. Upon receipt of the trigger signal, the measurement control unit 103 measures the color patch on the display using a sensor 104. After the measurement is finished, a measurement value is
20   outputted and the measurement control unit 103 outputs color patch signals to the color patch storage unit 100. Upon receipt of the color patch output signals, the color patch storage unit 100 outputs a subsequent color patch to the color patch display unit 101. A time
25   counted by the timer 102 can be set by a user or can

be obtained by referring to a file that stores a count time for each model or type of a display. Alternatively, a different count time can be set for each color patch.

Fig. 19 shows the configuration of the second
5   preferred embodiment of the display-measuring device of the present invention.

The color patch storage unit 100 stores a color patch required to measure the characteristic of a display. The color patch display unit 101 receives color
10   patch data and plots/displays the color patch on a display. After finishing the color patch display, the color patch display unit 101 transmits a trigger signal to the measurement control unit 103. Upon receipt of the trigger signal, the measurement control unit 103
15   measures the color patch on the display using the sensor 104. The measurement result is transmitted to a measurement value comparison unit 105 and is compared with a measurement result of the same color patch. As a result of the comparison, if the difference is big,
20   the measurement value comparison unit 105 transmits a trigger signal to the measurement control unit 103. Upon receipt of the trigger signal from the measurement comparison unit 105, the measurement control unit 103 performs measurement again and transmits the
25   measurement value to the measurement value comparison

unit 105. Alternatively, when the difference in a measurement value is judged to be small, the measurement value comparison unit 105 can output the latest measurement result. In this case, when transmitting

5 color patch output signals to the measurement control unit 103, a timer can be added. By measuring again after a specific time elapses, the number of measurements can be reduced.

Fig. 20 shows the configuration of the third

10 preferred embodiment of the display-measuring device of the present invention.

After finishing a color patch display, the color patch display unit 101 transmits a color patch display signal to the timer 102. The timer 102 initially stores

15 an arbitrary value (for example, "0"). Upon receipt of the color patch display signal, the timer 102 counts up to a set value and transmits a trigger signal to the measurement control unit 103 after a specific time elapses. Upon receipt of the trigger signal, the

20 measurement control unit 103 measures a color patch on a display using the sensor 104. First, an MPX 107 (for example, a buffer or selector) transmits the measurement result to the measurement value comparison unit 105. The measurement value comparison unit 105

25 compares measurement results. As a result of the

comparison, if the difference is big, the measurement value comparison unit 105 transmits a trigger signal to the measurement control unit 103. Upon receipt of the first measurement result of the color patch, the

5 measurement value comparison unit 105 transmits a counter start signal to a counter 106 instead of performing a comparison. Upon receipt of the count start signal, the counter 106 starts counting. When judging that the difference in a measurement value is small,

10 the measurement value comparison unit 105 outputs the latest measurement result, transmits a color patch output signal to the color patch storage unit 100 and further transmits a counter end signal to the counter 106. Upon receipt of the count end signal, the counter

15 106 stops counting and transmits the counting result to the timer 102. Simultaneously, the counter 106 transmits a switching signal to the MPX 107. The timer 102 sets a transmitted timer value. Upon receipt of the switching signal, the MPX 107 outputs the

20 measurement value to a terminal without performing any process.

Fig. 21 shows the configuration of the fourth preferred embodiment of the display-measuring device of the present invention.

25 The color patch storage unit 100 stores a color

patch required to measure the characteristic of a display. The color patch display unit 101 receives the color data and plots/displays the color patch. After finishing the color patch display, the color patch

5 display unit 101 transmits a trigger signal to the measurement control unit 103. Upon receipt of the trigger signal, the measurement control unit 103 measures the color patch on a display using the sensor 104. The measurement result is outputted from a terminal.

10 The measurement control unit 103 also transmits an image-switching signal to an image control unit 108. The image control unit 108 transmits the signal to an image storage unit 110 and also transmits a count start signal to a timer 109. The image storage unit 110

15 transmits a stored image (for example, an image composed of black only) to the color patch display unit 101. The color patch display unit 101 plots the image and transmits the image to a display. In this case, the color patch display unit 101 does not transmit a trigger

20 signal to the measurement control unit 103. Upon receipt of the count start signal, the timer 109 starts counting. After a specific pre-determined time elapses, the timer 109 transmits an elapse signal to the image control unit 108. Upon receipt of the elapse signal, the image

25 control unit 108 transmits an image-switching signal

to the color patch storage unit 100 and displays a subsequent image. A user can set a time to be counted by the counter 109 or the time can be obtained by referring to a file that stores a count time for each

5   model or type of display. Alternatively, a different time can also be set for each color patch.

Alternatively, instead of using a timer, images can be consecutively measured and the existence /non-existence of an after-image can also be detected.

10   Fig. 22 shows the configuration of the fifth preferred embodiment of the display-measuring device of the present invention.

The color patch storage unit 100 stores a color patch required to measure the characteristic of a

15   display. The color patch display unit 101 receives the color patch data and plots/displays the color patch on a display. After finishing the color patch display, the color patch display unit 101 transmits a trigger signal to the measurement control unit 103.Upon receipt

20   of the trigger signal, the measurement control unit 103 measures the color patch on the display using the sensor 104. The MPX 111 (for example, a selector or the like) outputs the measurement result to a terminal. The measurement control unit 103 also transmits an

25   image-switching signal to the image control unit 108

and also transmits the switching signal to an MPX 111.
The image control unit 108 transmits the signal to the
image storage unit 110. The image storage unit 110
transmits a stored image (for example, an image composed

5   of only black) to the color patch display unit 101.
The color patch display unit 101 plots the image and
transmits the image to a display. In this case, the
color patch display unit 101 transmits a trigger signal
to the measurement control unit 103 again. The MPX 111

10   transmits the measurement result to a measurement value
comparison unit 112. The measurement value comparison
unit 112 compares the measurement result of the image
with the previous measurement result. If the difference
in a measurement value is big, the measurement value

15   comparison unit transmits a trigger signal to the
measurement control unit 103. Upon receipt of the
trigger signal, the measurement control unit 103
performs   measurement   again   and   transmits   the
measurement value to the measurement value comparison

20   unit 112. Upon receipt of the image-switching signal,
the   image   control   unit   108   transmits   the
image-switching signal to the color patch storage unit
100 and displays a subsequent color patch.

Alternatively, before measurement, an image (for

25   example, an image composed of only black) can be

measured, which is not shown, and the result can be stored/used by the measurement value comparison unit 112. In this case, when the measurement value of a currently measured image becomes close to that of a

5   stored measurement result, the image control unit 108 transmits an image-switching signal and displays a subsequent color patch.

Fig. 23 shows the configuration of the sixth preferred embodiment of the display-measuring device

10 of the present invention.

According to the present invention, a counter 113 counts a time required to judge whether there is an after-image and the time is set as an interval. After that, there is no measurement of an image, and when

15 the count result of the counter 113 reaches the interval, a subsequent color patch is displayed.

An example of a method for modeling displays based on the measurement results of displays and setting each parameter of a model is described below.

20   The following three display models are assumed.

$$(\text{Output}) = (\text{Input})^{\gamma} \qquad \text{Model 1}$$

$$(\text{Output}) = a\,(\text{Input})^{\gamma} \qquad \text{Model 2}$$

$$(\text{Output}) = a\,(\text{Input})^{\gamma} + b \qquad \text{Model 3}$$

The equations include three variables (a, b, and

25 γ). Therefore, if there are at least two measurement

values, each parameter can be solved using simultaneous
equations. For example, it is assumed that measurement
results are as follows.

Table 1   Examples of measurement results and differences
          in measurement values for each model

No	INPUT	OUTPUT	MODEL 1	MODEL 2	MODEL 3
1	0	0.17	0	0	0.17
2	0.2	0.19	0.07373	0.11107	0.19406
3	0.4	0.278	0.22664	0.27348	0.28056
4	0.6	0.438	0.43712	0.46328	0.43978
5	0.8	0.677	0.69664	0.67338	0.67801
6	1	1	1	0.9	1
		Average output errors	0.05969	0.06373	0.00157

5   If the parameter of model 1 is calculated based on result
     No.4, γ =1.62 is obtained. If the parameters of model
     2 are calculated based on results Nos. 3 and 5, a=0.9
     and γ=1.3 are obtained. If the parameters of model 3
     are calculated based on results Nos. 1, 4 and 6, a=0.83,

10   b=0.17 and γ=2.2 are obtained. If the outputs of the
     respective models are calculated using each parameter
     value, the table at the right is obtained. The error
     of model 3 is the smallest. Therefore, the model of
     this display can be most closely approximated by the

15   following equation.

         (Output) = a (Input)$^{\gamma}$ + b   (a=0.8,   b=0.17
     and γ=2.2)

     Each of these parameter values is stored in a profile.

In an ICC profile, only display model (1) is assumed.
Setting such a plurality of models and storing the
parameters of a model with the smallest error in a
profile can implement more accurate color matching in
5   a CMS corresponding to such a plurality of models.

Fig. 24 shows the configuration of the seventh
preferred embodiment of the display-measuring device
of the present invention.

A color patch value storage unit 114 stores the
10   RGB values of a color patch. A color patch generation
unit 115 generates a color patch based on both the size
of the color patch stored in a size storage unit 116
and the RGB values stored in the color patch value
storage unit 114. In this case, first, an image of white
15   (255, 255, 255) is generated and is displayed on a
display. The color patch generation unit 115 transmits
a measurement start (trigger) signal to a measurement
control unit 118. The measurement control unit 118
performs control of a sensor 119 according to the
20   trigger signal and reads the measurement value of the
image displayed on the display. Then, the measurement
control unit 118 transmits a size modification signal
to the size storage unit 116. The size storage unit
116 transmits a size modification signal to a size
25   modification unit 117, stores a color patch of a size

smaller than the relevant color patch and transmits the color patch to the color patch display unit 101. The color patch display unit 101 displays a color patch of a size smaller than the relevant color patch and

5 the measurement control unit 103 measures the value. Then, both the measurement values are compared. If the latter is lighter than the former, it can be judged that power control has been exercised. In this case, the process described above is repeated reducing the

10 size gradually until both the measurement values become the same (stay in the allowable error range). When both the measurement results become the same, the measurement control unit 103 transmits a size-fixture signal to the size storage unit 116. The size storage

15 unit 116 stores the size obtained when both the measurement results become the same or at the size immediately preceding the relevant size, and uses the relevant size for subsequent color patchs.

The detecting method of a measurement error by

20 color additive-mixture is described below. Since color additive-mixture can be applied, the measurement value of a specific color C (r, g, b) equals the sum of red R (r, 0, 0), green G (0, g, 0) and blue B (0, 0, b). Although there is a small error due to a measurement

25 error, backward radiation or the like, the error remains

acceptable. Table 2 shows the measurement results of a CRT (FMV-DP978) manufactured by Fujitsu.

Table 2   CRT color additive-mixture performance

RGB value			Measurement value			Color additive-mixture value			Error
R	G	B	X	Y	Z	X	Y	Z	
128	0	0	14.33	8.096	1.874	–	–	–	–
0	128	0	13.95	25.38	4.657	–	–	–	–
0	0	128	10.16	5.629	45.65	–	–	–	–
128	128	0	26.65	32.32	5.172	28.29	33.48	6.531	2.417516
128	0	128	22.86	12.43	47.37	24.49	13.73	47.53	2.08948
0	128	128	22.32	29.67	49.78	24.11	31.01	50.31	2.295934
128	128	128	35.16	36.66	50.62	38.44	39.11	52.18	4.378499

(The errors are calculated according to sqrt
$\{(X1-X2)^2+(Y1-Y2)^2+(Z1-Z2)^2\}$)

5   In this table, for example, the color additive-mixture value of (R, G, B)=(128, 128, 0) is the sum of the measurement value of (R, G, B)=(128, 0, 0) and the measurement value of (R, G, B)=(0, 128, 0). As seen from this table, the errors in measurement

10   values (CIEXYZ values) all are 5 or less, and differences between X, Y and Z values all are 3 or less. By calculating an error between the sum of a measured secondary color (color in which two or more of R, G and B color elements are lit) or a measured tertiary

15   color (color in which all of R, G and B color elements are lit) and a primary color (one of R, G and B color

elements is lit), and a measurement value and by judging whether the error is equal to or less than a threshold value, the existence/non-existence of a measurement error can be detected.

5   A method for detecting a measurement error based on both the increase/decrease of the RGB values and XYZ values of a color patch is described below. Table 3 shows the measurement results of a CRT (FMV-DP978) manufactured by Fujitsu.

10

Table 3   Correlation between a measurement value
            and a color patch value

RGB Value			Measurement Value		
R	G	B	X	Y	Z
0	0	0	1.8858	1.4568	1.3481
0	0	64	3.6178	2.3585	11.2312
0	0	128	10.1569	5.6292	45.6539
0	0	191	20.5493	10.8486	101.304
0	0	255	38.4387	19.719	196.851

This table shows measurement values obtained when blue increases. As blue increases, all of the X, Y and Z values increase. As to an increase amount, the increase amount of the Z value is the greatest.
15   Similarly, as red or green increases, all of the X, Y and Z values increase, and in the case of red or green the increase amount of X and that of Y, respectively, are the greatest. Thus, by comparing a color patch value

with a measurement value, for example, if the measurement value decreases although the RGB value of a color patch increases or if the X value increases although blue increases, it can be judged that there

5   is a measurement error. In this case, by comparing measurement values immediately before and after, a measurement error can be detected.

With regard to color additive-mixture, the CIEXYZ values of white should be larger than those of

10   any other color. Therefore, by first measuring white, storing the CIEXYZ values and comparing a subsequent measurement value with the CIEXYZ values, a measurement error can be detected. If extraneous light penetrates a measurement instrument due to some cause, sometimes

15   a measurement value becomes larger than that of white. Such an error can be easily detected. In this case, not all of the X, Y and Z values, but one of the values, for example, only the Y value (luminance value), can also be compared.

20   Fig. 25 shows the configuration of the eighth preferred embodiment of the display-measuring device of the present invention.

A color storage unit 121 stores a color patch or the RGB values of a color patch required to generate

25   a TRC. The color patch display unit 101 plots the color

patch and displays the color patch on a display. The unit 101 also transmits a measurement start (trigger) signal to a measurement control unit 123. The measurement control unit 123 performs control of a

5   sensor 124 and transmits the measurement result to a TRC generation unit 125. The TRC generation unit 125 evaluates a plurality of TRCs based on the measurement data. A TRC selection unit 126 selects one of the TRCs based on the result of an accuracy calculation unit

10   127. A TRC with the highest accuracy can be simply selected. Alternatively, since a file size increases with the number of nodes of a TRC, the number of nodes of the most efficient TRC can be selected taking the file size into consideration. For example, if the

15   relationship between the number of nodes of a TRC and accuracy is as shown in Fig. 26, accuracy is suddenly improved as the number of nodes of a TRC increases when the number of nodes of a TRC is 32 (TRC=32) or less. Although, accuracy is gradually improved even if a TRC

20   is more than 32, the degree of effect is not the same as the modification in the number of nodes of a TRC. In this case, by selecting TRC=32 as an optimal TRC, the most effective profile can be generated when compared with a file size. Since a TRC is stored for

25   each of the R, G and B color elements, a profile size

has three times the number of nodes of a TRC. If the number of tags in a matrix profile is assumed to be 7 (wtpt, rXYZ,gXYZ, bXYZ, rTRC, gTRC and bTRC), the profile size is as follows (see Fig. 2).

5   128 bytes (profile header) + 88 bytes (tag table) + n (tag element)

A tag element stores seven tags. Of these, rXYZ, gXYZ, bXYZ and wtpt store the XYZ values of red, green blue and white, respectively. The fixed length of each size

10   is 20 bytes and the total is 80 bytes. rTRC, gTRC and bTRC store TRCs, and the size varies depending on the number of nodes of a TRC. If the number of nodes of a TRC is assumed to be n, the size is 12 + 2n. Therefore, the profile size is (332 + 6n) bytes. Thus, a profile

15   size can be estimated from the number of nodes of a TRC. If TRC=32, the profile size is 524 bytes, and if TRC=256, it is 1,868 bytes. However, there are tags for storing character strings, such as cprt, desc or the like, in addition to these tags. If these tags are

20   stored, the profile size further increases.

Fig. 26 shows the relationship between the number of nodes of a TRC and the accuracy of a profile generated by a TRC.

As shown in Fig. 26, if the number of TRCs exceeds

25   a specific value, accuracy is improved no further. A

TRC generation unit 125 generates a TRC and also calculates a γ coefficient, which is not shown. An accuracy calculation unit 127 compares accuracy obtained by using a TRC and accuracy obtained by using

5　a γ coefficient, which is not shown. If a high accuracy is obtained by using a TRC, a profile of a smaller size can be generated. If there is no big difference in performance between a TRC and a γ coefficient, by generating a profile that stores a γ coefficient, a

10　profile of a smaller size can be generated. A γ coefficient value can be calculated from a measurement value according to the following equation described in IEC-61966-3.

$$\gamma = \frac{1}{D}\left(n\sum_{i=1}^{n}p_i q_i - \sum_{i=1}^{n}p_i \sum_{i=1}^{n}q_i\right)$$

$$p_i = \log_{10} x_i$$

$$q_i = \log_{10} y_i$$

$$D = n\sum_{i=1}^{n}p_i^2 - \left(\sum_{i=1}^{n}p_i\right)^2$$

15　Calculation expression of γ coefficient

　　　The optimal number of TRCs depends on the types of a display, which is not shown. For example, since the tone reproduction curve of a CRT is smooth, high accuracy can be expected despite a small number of

20　measurement points. For example, if a display to be measured is a CRT and an LCD/PDP, the optimal number

of nodes of a TRC can be easily determined for each type of display using TRC=16 and TRC=64, respectively. A user can designate which display should be measured: a CRT or an LCD. Alternatively, in the case of Windows

5 95/98, the user can refer to registry information since the registry information stores the model names of displays in use.

Fig. 27(a) shows the γ characteristic of a display.

10 The γ characteristics of the R, G and B color elements of this display are almost the same. In such a display, the x and y chromaticity values of the non-color are the same. If R, G and B color elements are not balanced, as shown in Fig. 27(b), the x and

15 y chromaticity values of the non-color are different. If the curve with a small inclination (□), shown in Fig. 27(b), is assumed to be the tone reproduction curve of blue, the non-color located in the middle is bluish white. If two colors, white and gray, are measured and

20 their chromaticity values are compared, it can be judged whether the γ characteristics of the colors of this display are the same or different. If the difference between x and y chromaticity values is equal to or more than a pre-determined threshold value, a TRC is

25 calculated by individually measuring R, G and B color

elements. If the difference is less than the threshold value, there is no big dispersion. Therefore, by measuring the color tone of one of the color elements or white and copying/storing the measurement result

5   as the TRCs of R, G and B color elements, the number of measurements can be reduced to 1/3 what would be otherwise be required.

An ICC profile stores information in the form of a tag. Measured XYZ values are stored in the form

10   of a ratio between the measurement values of a reference color (D50) and those of white. If it is assumed that the XYZ values of the reference color and the measurement values of white are (X_{LS}, Y_{LS}, Z_{LS}) and $(X_{wtpt}, X_{wtpt}, X_{wtpt})$, respectively, a storage value (X_p, Y_p, Z_p)

15   can be calculated as follows.

$$X_p = X \cdot X_{LS}/X_{wtpt}$$

$$Y_p = Y \cdot Y_{LS}/Y_{wtpt}$$

$$Z_p = Z \cdot Z_{LS}/Z_{wtpt}$$

In this case, by storing measurement values X, Y and

20   Z, along with X_p, Y_p and Z_p, this method can be applied to a CMS in which color matching is available, taking the absolute values of color into consideration. These pieces of information can also be stored in a profile as a new tag. A new tag can be obtained by applying

25   to ICC. There are tags for storing arbitrary character

strings, such as cprt or the like. Alternatively, an arbitrary character string can be stored in such a tag without obtaining a new tag. An example of the procedure for generating different profiles for R, G and B color

5   elements from the measurement value of one color is described below.

The fact that there are different color temperatures in the same display means that their lightness ratios between R, G and B color elements

10   composing a color are different. A chromaticity value, which is information about color, can be expressed according to the following equations, with X, Y and Z values as variables.

$$x = \frac{X}{X+Y+Z}, y = \frac{Y}{X+Y+Z} \quad \cdots(4)$$

15   Although the XYZ values of red, green and blue of a display vary depending on different color temperatures, chromaticity values xy do not vary since X, Y and Z are all multiplied by the same value k. For example, the relationship between the XYZ values of

20   red R_{D50} at a color temperature of D50 and the XYZ values of red R_{9500K} at a color temperature of 9500K is as follows.

R_{D50} (X, Y, Z) = (X_{RD50}, Y_{RD50}, Z_{RD50})

R_{9500K} (X, Y, Z) = (X_{R9500K}, $Y_{RD9500K}$, $Z_{RD9500K}$)

$$= (k \cdot X_{RD50}, \quad k \cdot Y_{RD50}, \quad k \cdot Z_{RD50})$$

In the above equation, k is a proportional constant.

The same description applies to G and B color
5   elements. In white W, chromaticity varies. Since the
component ratio among R, G and B color elements varies,
the relationship between the XYZ values of white WD50
at a color temperature of D50 and the XYZ values of
white W9500K at a color temperature of 9500K is as
10   follows.

$$W_{D50} = (X_{WD50}, \quad Y_{WD50}, \quad Z_{WD50})$$

$$W_{9500K} = (X_{\bar{W}9500K}, \quad Y_{\bar{W}9500K}, \quad Z_{\bar{W}9500K})$$

$$= (k_R X_{RD50} + k_G X_{GR50} + k_B X_{BR50}, \quad k_R Y_{RD50} + k_G Y_{GD50}$$
$$+ k_B Y_{BD50}, \quad k_R Z_{RD50} + k_G Z_{GD50} + k_B Z_{BD50})$$

15   (5)

In the above equations, k_R, k_G, k_B are the
proportional constants of R, G and B color elements,
respectively.

If the Y value is defined, X and Z can be calculated
20   according to equation (4) as follows.

$$X = \frac{x}{y} Y, Z = \frac{1-x-y}{y} Y \quad \cdots (6)$$

International Illumination Committee CIE or the like
define chromaticity values xy at a specific color
temperature. Both xy chromaticity values at each color

temperature and the XYZ values at luminance $Y=1.0 cd/m^2$ are as follows.

Color Temperature	xy chromaticity value		XYZ values in case Y=1.0		
	x	y	X_c	Y_c	Z_c
9300K	0.2866	0.3044	0.9415	1	1.344
7500K	0.3004	0.3103	0.9681	1	1.255
6500K	0.3135	0.3237	0.9685	1	1.121
5000K	0.3451	0.3516	0.9815	1	0.8626
A	0.4476	0.4074	1.099	1	0.3559
C	0.3101	0.3163	0.9804	1	1.181
D65	0.3127	0.329	0.9505	1	1.089
D50	0.3457	0.3585	0.9643	1	0.8251

Table 4   xy chromaticity values and XYZ values
at color temperatures

As described above, if color temperature varies

5   in the same display, the following relationships hold

true.

(Relationship A) Chromaticity values xy do not

vary according to variation of a color temperature.

Therefore,

10   if in R, chromaticity values xy are R_1 (X, Y,

Z) at a color temperature, the values are R_2 ($k_R X$, $k_R Y$,

$k_R Z$) at another color temperature,

if in G, chromaticity values xy are G_1 (X, Y,

Z) at a color temperature, the values are G_2 ($k_G X$, $k_G Y$,

15    $k_G Z$) at another color temperature, and

if in B, chromaticity values xy are B_1 (X, Y,

Z) at a color temperature, the values are B_2 ($k_B X$, $k_B Y$, $k_B Z$) at another color temperature.

(relationship B) Since the XYZ values of white W are the sum of R, G and B values(equation (5)),

5      $W = (k_R X_R + k_G X_G + k_B X_B, k_R Y_R + k_G Y_G + k_B Y_B, k_R Z_R + k_G Z_G + k_B Z_B) = (X_C, Y_C, Z_C)$

(X_C, Y_C and Z_C are the XYZ values shown in Table 4)

As described above, by calculating constants k_R, k_G and k_B, the XYZ values of R, G and B color elements

10   in the case where color temperature varies can be obtained. k_R, k_G and k_B can be obtained by solving the following simultaneous linear equation with three unknowns.

$X_C = k_R X_R + k_G X_G + k_B X_B$

15     $Y_C = k_R Y_R + k_G Y_G + k_B Y_B$

$Z_C = k_R Z_R + k_G Z_G + k_B Z_B$

These equations can be solved according to a matrix equation, as follows.

$$\begin{pmatrix} X_R & X_G & X_B \\ Y_R & Y_G & Y_B \\ Z_R & Z_G & Z_B \end{pmatrix} \begin{pmatrix} k_R \\ k_G \\ k_B \end{pmatrix} = \begin{pmatrix} X_C \\ Y_C \\ Z_C \end{pmatrix}$$

20   If an inverse matrix is multiplied to both sides, the following can be obtained.

$$\begin{pmatrix} k_R \\ k_G \\ k_B \end{pmatrix} = \begin{pmatrix} X_R & X_G & X_B \\ Y_R & Y_G & Y_B \\ Z_R & Z_G & Z_B \end{pmatrix}^{-1} \begin{pmatrix} X_C \\ Y_C \\ Z_C \end{pmatrix}$$

If the inverse matrix in the right-hand-side is developed, the following can be obtained.

$$\begin{pmatrix} k_R \\ k_G \\ k_B \end{pmatrix} = \frac{1}{|XYZ|} \begin{pmatrix} Y_G Z_B - Y_B Z_G & X_B Z_G - X_G Z_B & X_G Y_B - X_B Y_G \\ Y_B Z_R - Y_R Z_B & X_R Z_B - X_B Z_R & X_B Y_R - X_R Y_B \\ Y_R Z_G - Y_G Z_R & X_G Z_R - X_R Z_G & X_R Y_G - X_G Y_R \end{pmatrix} \begin{pmatrix} X_C \\ Y_C \\ Z_C \end{pmatrix} \quad \cdots (7)$$

where $\dfrac{1}{|XYZ|} = \dfrac{1}{(X_R Y_G Z_B + X_B Y_R Z_G + X_G Y_B Z_R - X_B Y_G Z_R - X_G Y_R Z_B - X_R Y_B Z_G)}$

X_R, Y_R, Z_R, X_G, Y_G, Z_G, X_B, Y_B and Z_B are the XYZ values of the original R, G and B color elements of the display, and X_C, Y_C and Z_C are the XYZ values of a color temperature from the rXYZ, gXYZ and bXYZ tags of the original profile. By obtaining them from Table 4, k_R, k_G and k_B can be calculated according to equation (7). If k_R, k_G and k_B can be obtained, the XYZ values of R, G and B color elements can be calculated according to the relationship A. An example of the color temperature profile generating procedure is as follows.

[Example]

If a profile with the following tag information,

rXYZ = 0.3647, 0.1903, 0.0101

gXYZ = 0.3566, 0.6912, 0.0605

bXYZ = 0.2428, 0.1185, 0.7545

wtpt = 0.9414, 1.000, 1.3433,

is converted into a profile with the following chromaticity values xy of the measurement value of

5   white,

xy = (0.3156, 0.3361)

Step 1: The XYZ values of color temperature X are calculated from chromaticity xy.

If X and Z are calculated assuming Y=1.0,

10   $X_{color.temp.x}$ = 0.3156/0.3361 = 0.939

$Y_{color.temp.x}$ = 1.0

$Z_{color.temp.x}$ = (1-0.3156-0.3361)/0.3361 =1.0363

Step 2: The XYZ values of each of the R, G and B color elements of a reference profile are calculated

15   from tag information.

$X_R = X_{rXYZ} \cdot X_{wtpt}/X_{LS}$ = 0.3647×0.9414/0.9642 = 0.3560

$Y_R = Y_{rXYZ} \cdot Y_{wtpt}/Y_{LS}$ = 0.1903×1.0/1.0 = 0.1903

$Z_R = Z_{rXYZ} \cdot Z_{wtpt}/Z_{LS}$ = 0.0101×1.3433/0.8251 = 0.01644

20   $X_G = X_{gXYZ} \cdot X_{wtpt}/X_{LS}$ = 0.3566×0.9414/0.9642 = 0.3482

$Y_G = Y_{gXYZ} \cdot Y_{wtpt}/Y_{LS}$ = 0.6912×1.0/1.0 = 0.6912

$Z_G = YZ_{gXYZ} \cdot Z_{wtpt}/Z_{LS}$ = 0.0605×1.3433/0.8251 = 0.09850

$X_B = X_{bXYZ} \cdot X_{wtpt}/X_{LS}$ = 0.2428×0.9414/0.9642 = 0.2371

25   $Y_B = Y_{bXYZ} \cdot Y_{wtpt}/Y_{LS}$ = 0.1185×1.0/1.0 = 0.1185

$Z_B = Z_{bXYZ} \cdot Z_{wtpt}/Z_{LS} = 0.7545 \times 1.3433/0.8251 = 1.2284$

Step 3: The proportional constants k_R, k_G and k_B of each of R, G and B color elements are calculated.

The fact there are different color temperatures means that the ratio among R, G and B color elements varies. However, in R, G and B, which are primary colors, chromaticity values xy do not vary even if color temperature varies (Relationship A). The calculation process is omitted here.

If the following matrix equation is solved,

$$\begin{pmatrix} k_R \\ k_G \\ k_B \end{pmatrix} = \begin{pmatrix} X_R & X_G & X_B \\ Y_R & Y_G & Y_B \\ Z_R & Z_G & Z_B \end{pmatrix}^{-1} \begin{pmatrix} X_C \\ Y_C \\ Z_C \end{pmatrix} = \begin{pmatrix} 0.3560 & 0.3482 & 0.2371 \\ 0.1903 & 0.6912 & 0.1185 \\ 0.0164 & 0.0985 & 1.2284 \end{pmatrix}^{-1} \begin{pmatrix} 0.939 \\ 1.0 \\ 1.0363 \end{pmatrix}$$

$k_R = 1.163$, $k_G = 0.998$ and $k_B = 0.748$ can be obtained.

Step 4: The XYZ values of each of the R, G and B color elements after color temperature modification are calculated.

$X'_R = X_R \times k_R = 0.3560 \times 1.163 = 0.4140$

$Y'_R = Y_R \times k_R = 0.1903 \times 1.163 = 0.2213$

$Z'_R = Z_R \times k_R = 0.01644 \times 1.163 = 0.0191$

$X'_G = X_G \times k_G = 0.3482 \times 0.998 = 0.3475$

$Y'_G = Y_G \times k_G = 0.6912 \times 0.998 = 0.6898$

$Z'_G = Z_G \times k_G = 0.0985 \times 0.998 = 0.0983$

$X'_B = X_B \times k_R = 0.2371 \times 0.748 = 0.1774$

$Y'_B = Y_B \times k_R = 0.1185 \times 0.748 = 0.0886$

$Z'_B = Z_B \times k_R = 1.2284 \times 0.748 = 0.9188$

Step 5: wtpt, rXYZ, gXYZ, bXYZ and wtpt are calculated.

$X'_{wtpt} = X_{color.temp.X} = 0.939$

5    $Y'_{wtpt} = Y_{color.temp.X} = 1.0$

$Z'_{wtpt} = Z_{color.temp.X} = 1.0363$

$X'_{rXYZ} = X'_R X_{LS}/X'_{wtpt} = 0.4140 \times 0.9642/0.939 = 0.4251$

$Y'_{rXYZ} = Y'_R Y_{LS}/Y'_{wtpt} = 0.2213 \times 1.0/1.0 = 0.2213$

10    $Z'_{rXYZ} = Z'_R Z_{LS}/Z'_{wtpt} = 0.0191 \times 0.8251/1.0363 = 0.0152$

$X'_{gXYZ} = X'_G X_{LS}/X'_{wtpt} = 0.3475 \times 0.9642/0.939 = 0.3568$

$Y'_{gXYZ} = Y'_G Y_{LS}/Y'_{wtpt} = 0.6898 \times 1.0/1.0 = 0.6898$

15    $Z'_{gXYZ} = Z'_G Z_{LS}/Z'_{wtpt} = 0.0983 \times 0.8251/1.0363 = 0.0783$

$X'_{bXYZ} = X'_B X_{LS}/X'_{wtpt} = 0.1774 \times 0.9642/0.939 = 0.1822$

$Y'_{bXYZ} = Y'_B Y_{LS}/Y'_{wtpt} = 0.0886 \times 1.0/1.0 = 0.0866$

20    $Z'_{bXYZ} = Z'_B Z_{LS}/Z'_{wtpt} = 0.9188 \times 0.8251/1.0363 = 0.7315$

Step 6: They are stored.

By storing a profile that stores wtpt, rXYZ, gXYZ and bXYZ in step 5, a profile with a different color
25   temperature can be generated.

According to the procedure described above, a profile with a different color temperature can be generated by the measurement of one color.

Fig. 28 shows the dump code of a matrix profile.

5   A TRC is stored in the double underlined areas shown in Fig. 28. Since a TRC is stored using two bytes, values 0, 5407, 18841, 39075 and 65535 are stored. If the values are normalized using 65563, then 0.00825, 0.2875, 0.5963 and 1.0 can be obtained. These are color

10   tone data. In a TRC, an output value obtained by equally dividing an input is stored. Since in this example, the number of TRCs is five, relationships between inputs and outputs (input, output) = (0,0), (0.25, 0.0825), (0.5, 0.2875), (0.75, 0.5963) and (1.0, 1.0) are stored.

15   To modify this profile to γ2.2, it is sufficient if values obtained by multiplying $0.25^{2.2}=0.0474$, $0.5^{2.2}=0.2176$ and $0.75^{2.2}=0.5310$ by 65535 are stored. Therefore, it is sufficient if the double underlined values are rewritten as 0000, 0c22, 37b4, 87ef and ffff

20   (see claim 29). In reality, since there are TRCs for R, G and B color elements in a profile, the number of areas to be rewritten is three.

As to an LUT profile, by automatically selecting a profile with the highest accuracy, the workload of

25   a user can be reduced, as in the case of a matrix profile.

Fig. 29 shows the details of the configuration shown in Fig. 25.

In the TRC generation unit 125, all measurement data are temporarily stored in a measurement data storage unit 125-1. A peak value storage unit 125-2 stores the XYZ values of the maximum color (for example, in the case of red, RGB values (255, 0, 0)) of the measurement data. A TRC calculation unit 125-3 calculates a ratio to the maximum color by dividing each measurement data value by the measurement data value of the maximum color. Since according to the regulations of an ICC profile, a TRC is stored using 16 bits, the maximum value is 65535. Therefore, a TRC can be obtained by multiplying the ratio of each piece of color tone data to the maximum color calculated earlier, by 65535. A TRC interpolation unit 125-4 increases the number of TRCs by interpolating the generated TRCs. For the interpolation, a simple linear interpolation, interpolation similar to a γ curve ((input)=(output)$^{\gamma}$) or the like, are used. Conversely, a TRC thinning unit 125-5 reduces the number of nodes of a TRC by thinning out a part of the TRC. Thus, the TRC generation unit 125 generates a plurality of TRCs with different numbers of nodes.

The TRC selection unit 126 temporarily stores

the plurality of generated TRCs and transmits each of the TRCs to the accuracy calculation unit 127.

In the accuracy calculation unit 127, a color tone calculation unit 127-1 calculates the color tone value of specific RGB values based on the received TRC and transmits the calculation result to an error calculation unit 127-2. The error calculation unit 127-2 compares a measurement value obtained by measuring a color patch with RGB values with the output of the color tone calculation unit 127-1, detects the TRC with the smallest error and transmits the result to the selector 126-2 of the TRC selection unit 126.

Upon receipt of the detection result of the accuracy calculation unit 127, the selector 126-2 outputs the TRC with the highest accuracy to the profile generation unit125.

Fig. 30 shows the configuration of the ninth preferred embodiment of the display-measuring device of the present invention.

The color patch storage unit 129 stores a color patch required to generate an LUT or the RGB value of the color patch. The color patch unit 130 plots and displays the color patch on a display. The unit 130 also transmits a measurement start (trigger) signal to the measurement control unit 131. The measurement

control unit 131 transmits the measurement result to
an LUT generation unit 133 by performing control of
a sensor 132. The LUT generation unit 133 generates
LUTs composed of different numbers of grids. The

5   accuracy calculation unit 135 evaluates the plurality
of LUTs generated by the LUT generation unit 133. To
evaluate the accuracy, the LUT with the highest accuracy
can simply be selected. As the number of LUTs increases,
the file size increases. Therefore, the most efficient

10   number of LUTs can also be selected by taking a file
size into consideration. As in the case of a matrix
profile, the optimal number of grids is fixed to some
extent for each model or type of a display. Therefore,
the optimal number of grids for each model or type of

15   a display can also be stored in a file and the number
of grids can also be set depending on the type or model
of a display.

    Fig. 31 shows the details of the configuration
shown in Fig. 30.

20   In the LUT generation unit 133, a measurement
data storage unit 133-1 temporarily stores all
measurement data. The output of a measuring instrument
is usually XYZ values, and the values of an LUT profile
is L*a*b* values. L*a*b* values can be obtained from

25   XYZ values according to a calculation expression. An

XYZ→L*a*b* conversion unit 133-2 converts XYZ values into L*a*b* values and transmits the L*a*b* values to an LUT calculation unit 133-3. The LUT calculation unit 133-3 generates an LUT in which the input RGB and output

5   L*a*b* are related to each other. An LUT interpolation unit 133-4 increases the number of LUTs by interpolating the generated LUTs. For the interpolation, a simple linear interpolation, interpolation similar to a γ curve ((input)=(output)^{γ}) or the like are used.

10 Conversely, the LUT thinning unit 133-5 reduces the number of LUTs by thinning out a part of the LUT. Thus, the LUT generation unit 133 generates a plurality of LUTs with different numbers of LUTs.

The LUT selection unit 134 temporarily stores

15 the plurality of generated LUTs and transmits each of the LUTs to the accuracy calculation unit 135.

In the accuracy calculation unit 135, an LUT output value calculation unit 135-1 calculates the color tone value of specific RGB value based on the

20 received LUT and transmits the calculation result to an error calculation unit 135-2. The error calculation unit 135-2 compares the measurement value obtained by measuring a color patch with RGB values with the output value of the LUT output value calculation unit, detects

25 the LUT with the smallest error and transmits the result

to the selector 134-2 of the LUT selection unit 134.

Upon receipt of the detection result of the accuracy calculation unit 135, the selector 134-2 outputs an LUT with the highest accuracy to the profile generation unit136.

Fig. 32 shows the configuration of the tenth preferred embodiment of the display-measuring device of the present invention.

A color tone color patch storage unit 137 stores a color patch required to measure color tone data. A color patch display unit 138 displays the color patch on a display and transmits a measurement start (trigger) signal to a measurement control unit 139. The measurement control unit 139 transmits the trigger to a sensor 140 and measures the color of the color patch on the display. A color tone data storage unit 141 stores the measurement value. After the measurement of color tone data, a grid data calculation unit 142 generates grid data from the stored color tone data. For example, the color tone data are as follows:

Table 5   Example of the measurement result of color
              tone data

R	G	B	X	Y	Z
0	0	0	0	0	0
128	0	0	20. 4	15. 165	5. 25
255	0	0	40. 8	30. 33	10. 5

0	128	0	10.09	25.31	8.665
0	255	0	20.18	50.62	17.33
0	0	128	4.51	4.525	41.085
0	0	255	9.02	9.05	82.17

The following data of three grids can be generated by color additive-mixture.

Table 6   Data of three grids calculated by
color additive-mixture

R	G	B	X	Y	Z
0	0	0	0	0	0
128	0	0	20.04	15.16	5.25
255	0	0	40.08	30.33	10.5
0	128	0	10.09	25.31	8.66
128	128	0	30.13	40.47	13.91
255	128	0	50.17	55.64	19.16
0	255	0	20.18	50.62	17.33
128	255	0	40.22	65.78	22.58
255	255	0	60.26	80.95	27.83
0	0	128	4.51	4.52	41.08
128	0	128	24.55	19.68	46.33
255	0	128	44.59	34.85	51.58
0	128	128	14.6	29.83	49.74
128	128	128	34.64	44.99	54.99
255	128	128	54.68	60.16	60.24
0	255	128	24.69	55.14	58.41
128	255	128	44.73	70.3	63.66
255	255	128	64.77	85.47	68.91
0	0	255	9.02	9.05	82.17
128	0	255	29.06	24.21	87.42
255	0	255	49.1	39.38	92.67
0	128	255	19.11	34.36	90.83
128	128	255	39.15	49.52	96.08
255	128	255	59.19	64.69	101.33
0	255	255	29.2	59.67	99.5

| 128 | 255 | 255 | 49. 24 | 74. 83 | 104. 75 |
| 255 | 255 | 255 | 69. 28 | 90 | 110 |

The profile generation unit 143 generates a profile based on the grid data.

Since a display with high color additive-mixture performance, such as a CRT, generates grid data not greatly different from actual values, a profile with high accuracy can be generated. However, since a part of LCDs or the like has low color additive-mixture performance, sometimes a profile generated from the color additive-mixture value has low accuracy . In such a case, a part of colors, for example white (255, 255, 255) is measured and the measurement value and the color additive-mixture value are compared. If the difference is less than a pre-determined threshold value, the display is judged to have high color additive-mixture performance and a profile is generated from the color additive-mixture value. If the difference is more than the threshold value, the display is judged to have low color additive-mixture performance and the grid data are measured. By checking color additive-mixture performance, a profile with low accuracy can be prevented from being generated.

Fig. 33 shows the configuration of the eleventh

preferred embodiment of the display-measuring device of the present invention.

According to the present invention, a TRC generation unit 149 generates a TRC for a matrix profile based on a measurement result, and an LUT generation unit 148 generates an LUT for an LUT profile. An accuracy judgment unit 150 compares the accuracy of a TRC with that of an LUT, and outputs the profile with the higher accuracy to a profile generation unit 161 through an MPX 160 (selector or the like). According to the present invention, the profile with higher accuracy is automatically selected and outputted.

An LUT profile requires a larger number of measurements than a matrix profile. For example, a matrix profile with nine color tones requires only the measurement of 28 colors of a color patch, while an LUT profile with nine grids requires the measurement of 729 colors. As to a display, in the case of a CRT, a matrix profile has higher accuracy than an LUT profile, and even in the case of a part of LCDs and some PDPs, a matrix profile has higher accuracy than an LUT profile. Therefore, first, measurement for a matrix profile is conducted and only the accuracy of a TRC is detected. If the accuracy of a TRC is higher than the pre-determined accuracy, both measurement for an LUT

profile and profile generation are not performed and a matrix profile is outputted. Thus, both measurement time and generation time can be reduced.

It is determined to some extent, depending on
5   the models or types of display, which is better, a matrix profile or an LUT profile. In most cases of a CRT, a matrix profile has higher accuracy and in most cases of an LCD/PDP, an LUT profile has higher accuracy. A profile, the type of which is designated for each model
10 or type of a display can also be stored, and a type can also be selected depending on the models or types of a display.

Fig. 34 shows the configuration of the twelfth preferred embodiment of the display-measuring device
15 of the present invention.

An RGB value storage unit 162 stores the RGB values of a color patch. A color patch generation unit 163 generates a color patch based on the RGB values and displays the color patch on a display. A measurement
20 control unit 164 transmits a trigger signal to a sensor 165, measures color on the display and transmits the measurement result to a comparison/judgment unit 167. A profile for evaluation is transmitted to a profile operation unit 166, the output of the RGB value storage
25 unit 162 is calculated and the calculation result is

transmitted to a comparison control unit 167. The comparison control unit 167 compares both values. If the difference is less than a pre-determined value, an "OK" notification is sent to a user. If the difference

5   is equal to or more than the threshold value, an "NG" notification is sent to a user. Since a human being performs color matching, the accuracy of a profile should be better if judged by human eyes than by a numeric value. In a profile, an image is reproduced using both

10   information for converting RGB values into common color signals and information for inversely converting common color signals into RGB values. If a profile can be correctly generated, the difference between an original image and the conversion image will not be

15   recognized. Displaying an original image and the conversion image on a display and enabling a user to recognize the difference is performed to judge the accuracy of a profile. It is preferable to evaluate a profile immediately after profile generation.

20   Fig. 35 shows dispersion in the case where a human being, instead of a comparison control unit, performs judgment in the twelfth preferred embodiment.

An image storage unit 170 stores an image for evaluation (a color patch, a natural image or the like).

25   The image storage unit 170 transmits an image for

evaluation to an image conversion unit 172. The image conversion unit 172 converts the image for evaluation into common color signals, such as XYZ and L*a*b*, according to the information of a profile stored in
5   a profile storage unit 174. An image inverse-conversion unit 173 inversely converts the common color signals into RGB values again according to the information of the profile. An image display unit 171 displays both the image for evaluation stored in the image storage
10   unit 170, which is a base, and the conversion image, the color of which is converted by a profile on a display. A user makes a comparison by eye of the two images displayed on the display, it is judged that "color is unnatural", " a difference is clearly recognized",
15   "although a difference is recognized, it is allowable", "no difference can be recognized" or the like, and the judgment result is transmitted to a judgment result output unit 175. The judgment result output unit 175 outputs a control signal for a statement, such as " to
20   output a generated profile", "to discard a generated profile and to generate a profile again" or the like, based on the user's evaluation result.

As described above, the present invention can solve the following conventional problems in the
25   generation of a profile and can generate a profile with

high accuracy.

(1)   Color stability immediately after display

(2)   After-image of displayed color

(3)   Stability at the time of the start of display

5   (4)   Display in which display luminance fluctuates

(5)   Measurement error

(6)   Information amount of a matrix profile

(7)   Number of measurements of tone reproduction curve

(8)   Accuracy of the information of a profile

10   (9)   Troubles in both display setting and profile generation

(10) Number of grids of an LUT profile

(11) Number of measurements of grid data

(12) Selection of a profile type

15   (13) Confirmation of profile accuracy

The present invention can provide a method for generating a profile for color conversion with high accuracy and is used to display an image on a display or the like and can match the color appearance of images
20   displayed with different equipment with high accuracy.